

Plasma display screen having a reflection layer

The invention relates to a plasma display screen comprising a carrier plate, a transparent front plate, a rib structure which divides the space between the carrier plate and the front plate into plasma cells, which are filled with a gas, and comprising one or more electrode arrays on the front plate or on the front plate and the carrier plate to generate corona discharges in the plasma cells, and comprising a phosphor layer and a reflection layer.

The basic principle of a plasma display screen consists in that crossed electrode strips form a matrix, and a gas discharge taking place between them causes pixels to light up. The monochrome versions of the first plasma display screens used the generated light directly. However, as a result of the orange-red color caused by the neon-gas filling, these plasma display screens never became popular and were used only in a very specific market, where their immunity to high magnetic interference fields, mechanical vibrations and extreme temperatures is important, such as in military applications, medical applications, such as NMR diagnostics, and in industrial applications, such as aluminium electrolysis and power station.

Currently, the color versions of the plasma display screens are much more successful than the old monochrome plasma display screens. In the color versions, the gas filling is, for example, a mixture of helium, neon and xenon. In the discharge, ultraviolet radiation is formed which excites phosphors arranged in stripes, causing visible light to be emitted in red, green and blue. The electro-optical efficiency of the color plasma display screens is still unsatisfactory, however, which can be attributed to the fact that a two-stage process is necessary to generate visible light. The efficiency of a plasma display screen comprising a phosphor layer is decisively determined by how completely the generated UV light is absorbed in the phosphor and how completely the generated visible light subsequently leaves the plasma display screen in the direction of the observer. Complete absorption of the generated UV light could be attained by applying the phosphor layer in the largest possible thickness. However, this possibility is limited by the fact that the ribs of the rib structure cannot be manufactured in every desired height, and the available space in the plasma cell is necessary for the gas discharge. Therefore, a substantial part of the UV radiation is customarily transmitted through a comparatively thin phosphor layer and subsequently

absorbed in the carrier plate, without being converted to visible light and without reaching the observer.

In EP 0 782 166 it is disclosed that the luminance of a plasma display screen can be increased by providing a reflecting surface on its front side or by providing a plurality of reflecting surfaces on the rear side and/or on the side walls of the plasma cells of the plasma display screen. The reflecting surfaces can be formed, for example, by the polished surfaces of the electrodes.

It is an object of the invention to provide a plasma display screen wherein the efficiency with which visible light issues from the plasma cells is increased, while unnecessary light losses are precluded and the luminance of the plasma display screen is improved.

In accordance with the invention, this object is achieved by a plasma display screen comprising a carrier plate, a transparent front plate, a rib structure which divides the space between the carrier plate and the front plate into plasma cells, which are filled with a gas, and comprising one or more electrode arrays on the front plate or on the front plate and the carrier plate to generate corona discharges in the plasma cells, and comprising a phosphor layer and a reflection layer, which reflection layer contains a non-metallic powder having a refractive index for the wavelength range from 147 nm to 700 nm of  $n = n_{\text{real}} + ik$ , where  $n > 1.3$  and  $k < 0.05$ , said powder having an average grain diameter of  $100 \text{ nm} < d < 1000 \text{ nm}$ . "i" is the mathematical symbol for the imaginary unit.

Such a layer serves as a reflection layer for UV radiation and visible light in the wavelength range from 147 to 700 nm. The UV photons which upon passing through the phosphor layer for the first time have not excited the phosphors so as to make them light up, are reflected and pass through the phosphor layer again, until they are either absorbed or leave the phosphor layer again. In this manner, the probability of UV radiation being absorbed and visible light being excited in the phosphor layer is increased substantially. The conversion of UV radiation to visible light is improved. By virtue of the fact that the material in the reflection layer is in the form of a powder having an average grain diameter of  $100 \text{ nm} < d < 1000 \text{ nm}$ , said material spreads the light in all directions and the diffuse reflection of the layer is very advantageously improved. Further advantages of such a layer are that a) phosphors having a larger grain size distribution can be used without this necessarily leading to an increased thickness of the layer, which has a favorable effect on the plasma-discharge efficiency, b) a reduction of phosphor in the phosphor layer leads to a reduction of costs and c) the electrical properties of the plasma cells can be more

satisfactorily adapted and, in particular, the voltage range wherein all plasma cells can be switched on and off is optimized.

Within the scope of the invention, it is preferred that the reflection layer has a layer thickness  $s > 1 \mu\text{m}$ .

5 It is particularly preferred that the gas comprises xenon and that the non-metallic powder is selected from the group formed by  $\text{MgF}_2$ ,  $\text{MgO}$ ,  $\text{SiO}_2$  and  $\text{Al}_2\text{O}_3$ . These materials reflect UV light which has a wavelength of 147 to 200 nm and which originates, for example, from a xenon gas discharge.

10 It may also be preferred that the reflection layer is a multilayer, enabling the reflection at the layer to be increased.

These and other aspects of the invention will be apparent from and elucidated with reference to the embodiments described hereinafter.

In the drawings:

15 Fig. 1 is a diagrammatic, cross-sectional view of the structure of a AC plasma display screen in accordance with the invention.

Light excitation caused by the UV radiation of a gas discharge is the basic principle of all types of plasma displays. Plasma displays can be divided into DC addressed display screens and AC addressed display screens. The difference between them relates to the way in which current limitation takes place.

20 Fig. 1 shows an example of a plasma cell of an AC plasma display. Such an AC plasma display screen is composed of a transparent front plate 1 and a carrier plate 2, which are kept at a distance from each other and are hermetically closed at the periphery. The space between the two plates forms the discharge space 3, which is bounded by the protective layer and the phosphor layer. Customarily, both the front plate and the carrier plate are made of glass. Individually drivable plasma cells are formed by a rib structure 13 of dividing ribs. A plurality of transparent picture electrodes 6, 7 are arranged in strips on the front plate. The associated control electrodes 11 are provided on the carrier plate at right angles to said picture electrodes, thus enabling a discharge to be ignited at every crossing point.

30 The discharge space is filled with a suitable discharge gas, for example xenon, a xenon-containing gas, neon or a neon-containing gas. The gas discharge is ignited between the picture electrodes 6, 7 on the front plate. To preclude direct contact between the plasma and the picture electrodes 6, 7, the latter are covered with a dielectric layer 4 and a protective layer 5. In the discharge zone, the gas is ionized and a plasma 9 is formed, which emits UV radiation 12. The emitted UV radiation excites pixel-structured red, green and blue phosphors

so as to emit light in the visible region 14, resulting in a perceived color. The pixels of the plasma display screen in the three primary colors red, blue and green are formed by a phosphor layer 10 on at least a part of the carrier plate and/or the walls of the dividing ribs in the plasma cells. The reflection layer 8 is arranged between the rear side of the phosphor layer and the carrier plate, and reflects the UV radiation which has not been absorbed in the phosphor layer, such as visible light. The reflection layer particularly reflects light in the wavelength range between 147 and 700 nm. In the embodiment in accordance with Fig. 1, the reflection layer 8 also extends on the side walls of the plasma cells between the phosphor layer 10 and the ribbed structure 13. It is not necessary, however, for the reflection layer to cover the entire rear wall or the entire side walls of the plasma cells. It is sufficient if the rear wall and/or the side walls are at least partly covered.

Such a reflection layer comprises a non-metallic powder having a refractive index for the wavelength range from 147 nm to 700 nm of  $n = n_{\text{real}} + ik$ , where  $n > 1.3$  and  $k < 0.05$ , said non-metallic powder having an average grain diameter of  $100 \text{ nm} < d < 1000 \text{ nm}$ . Such a reflection layer can be formed, for example, by a layer of a powder composed of  $\text{MgF}_2$ ,  $\text{MgO}$ ,  $\text{SiO}_2$  or  $\text{Al}_2\text{O}_3$  having the appropriate granularity.

The reflection layer may alternatively be composed of several layers of non-metallic powders of the type mentioned hereinabove, having matching refractive indices, to increase the reflection. It is preferred that the grain diameter of the layers decreases in the direction of the carrier plate in order to obtain layers having an optically increasing density.

Dependent upon the composition of the gas in the plasma cell, the spectral intensity of the gas discharge changes. Gas mixtures comprising less than 30 vol.% xenon emit substantially resonant radiation at 147 nm, gas mixtures comprising more than 30 vol.% xenon emit excimer radiation at 172 nm. A particularly high efficiency of the reflection is obtained when the material used for the reflection layer is adapted, as regards chemical composition, layer thickness  $s$  and grain diameter  $d$  in accordance with Table 1 and Table 2, to the spectral intensity of the UV radiation. For UV light of a longer wavelength, use is preferably made of powders having a larger grain diameter.

Table 1: Spectral intensity maximum at 147 nm

Material	Average Diameter $d_{50\%}$ [nm]	Layer thickness [ $\mu$ m]	Reflection (147 nm)	Reflection (550nm)
SiO <sub>2</sub>	500	2.0	74%	76%
	250	2.0	90%	72%
	250	5.0	95%	87%
	100	2.0	97%	50%
MgF <sub>2</sub>	250	2.0	86%	60%

5 Table 2: Spectral intensity maximum at 170 nm

Material	Average Diameter $d_{50\%}$ [nm]	Layer thickness [ $\mu$ m]	Reflection (170 nm)	Reflection (550nm)
Al <sub>2</sub> O <sub>3</sub>	250	2.0	40%	80%
MgO	250	1.0	78%	70%
	500	2.0	75%	83%
	250	5.0	90%	90%

To manufacture the reflection layer use can be made of dry coating methods, for example electrostatic deposition or electrostatically assisted dusting, as well as  
 10 wet coating methods, for example screen printing, dispenser methods, wherein a suspension is introduced using a nozzle moving along the channels, or sedimentation from the liquid phase.

For the wet coating methods, the pigments must be dispersed in water, an organic solvent, if necessary in combination with a dispersing agent, a surface-active agent  
 15 and a defoaming agent or a binder additive. Organic and inorganic binders capable of withstanding an operating temperature of 250 °C without decomposing, embrittling or discoloring can suitably be used as the binder additives for plasma display screens.

Although the invention has been described with reference to an AC color plasma display screen, the application of the invention is not limited to this type of plasma display screen, but also includes, for example, DC color plasma display screens and monochromatic AC and DC plasma display screens.